Numerical Study of Spudcan Penetration Induced Loading on an Adjacent Jacket Pile in Soft Clays

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ABSTRACT

A mobile jackup is an important facility in offshore oil and gas development and often works in close proximity to a permanent jacket platform. The unique operation method and foundation tip (spudcan) configurations of jackups have induced a number of geotechnical challenges. Among them, an important issue is that the spudcan will displace a large volume of soil during penetration and may induce severe stresses on adjacent piles supporting the jacket platform. Though having general principals, the current industry code does not provide detailed guidance that engineers can follow specifically in practice to quantify this effect. Thus, a practical approach was developed in this paper in which the complicated phenomenon was numerically solved in two steps: Firstly, the soil displacement of free field around the spudcan was numerically studied using the large deformation technology. The induced soil displacement was found heavily dependent on the soil deformation characteristics such as $e_50$. Secondly, the conventional beam-column method using P-Y soil springs was adopted to compute the soil displacement induced loading on the jacket pile. On the contrary, the induced pile loading was found not sensitive to the variation of soil $e_50$ within a reasonable range, provided that the matching P-Y curves to the soil displacement in free field are used in the sequential analysis. The above approach was validated by centrifugal experiment results published in the past. In addition, the paper discussed how to set up an appropriate boundary condition at the pile head where the pile is connected with the jacket structures, and how to combine the spudcan induced loading with the upstructural loading to determine the ultimate status of a jacket pile. Both items have been neglected in the past study but may have profound effect on the final results.

KEY WORDS: Spudcan; Clay; Soil Displacement; Numerical Simulation; ALE; Tracer Particle; Beam-Column Analysis.

INTRODUCTION

A mobile jackup, typically consisting of a platform, elevating system and extendable legs, often works in close proximity to a permanent Jacket in offshore oil and gas development, for workover and drilling purposes. To ease penetration and extraction of the foundation, and also enhance the on-bottom stability under operational and environmental conditions, the jackup leg is always equipped with an enlarged tip, the so called spudcan, which is or nearly axisymmetric and with the outmost diameter that can reach 20 meters or more.

The unique operation method and foundation configurations of jackups have induced a number of geotechnical challenges. Among them, an important issue is that the spudcan will displace a large volume of soil during penetration and may induce severe stresses on adjacent piles supporting a jacket platform as sketched in Figure 1. If the jackup is positioned too close to the jacket, the induced stress added with the original pile stress from the upstructural loading may exceed the normal design limits and jeopardize the supporting piles and so the whole jacket platform. According to the Health and Safety Executive Report (HSE, 2004), 10% of the total 230 jackup accidents that were published before 2004 are attributed to spudcan-pile interaction. As a result, how to appropriately position the jackup to a jacket platform becomes a critical issue especially in early stage of a project when design engineers have more leverage to select jackups, optimize jacket configurations and evaluate the pile economics. A good solution will make balance between two contradicting facts: in one hand, the jackup should be close enough to the jacket to fulfill the operation purpose; on the other hand, the jackup should not be too close that may overstress the jacket piles. The dilemma becomes more prominent with increasing water depth where larger jackets and jackups will be more likely used.

Figure 1 Sketch of Spudcan Penetration Induced Loading on Adjacent Jacket Piles

Unfortunately, the current industry code does not provide detailed guidance on this issue. The main content of SNAME (2008) states that if the spudcan penetration is deep and also the clear proximity between the spudcan and a nearby pile is “closer than one spudcan diameter (1D), then analysis by the platform owner is recommended to determine the consequence of the induced pile loading”. Obviously this “1D” definition does not satisfy the interest of most platform owners. In